Active Loudspeakers and DSP: A Simplified Path to Perfection

By Steve Mowry

In the vast majority of loudspeakers, the low-level output signal from a CD or DVD player is the input to a receiver or preamplifier (control center), with the output from the preamplifier being the input to the power amplifier(s), ~1.0V. In these cases, each loudspeaker is connected to the power amplifier's output terminals using a single pair of "cables." However, between the power amplifier and the audio transducers, there is a passive RLC network. The power amplifier sees the RLC network and the audio transducers (***Fig. 1***).

To implement a reasonable crossover and any equalization or impedance compensation is a difficult task, to say the least, that usually becomes an empirical process (build and try) at some point. Degradation and variability of the high-level audio signal is simply unavoidable. One alternative is a full-range audio transducer that eliminates the need for a crossover network but not for equalization or impedance compensation.

ACTIVE LOUDSPEAKERS

Another alternative is active loudspeakers. In these cases, multiple power amplifiers are used and the crossover(s) and equalization are implemented electronically at low-level and typically between the preamplifier and the power amplifier with regard to the audio signal path. This is sometimes referred to as "bi-amp" or "tri-amp" for active two-way and

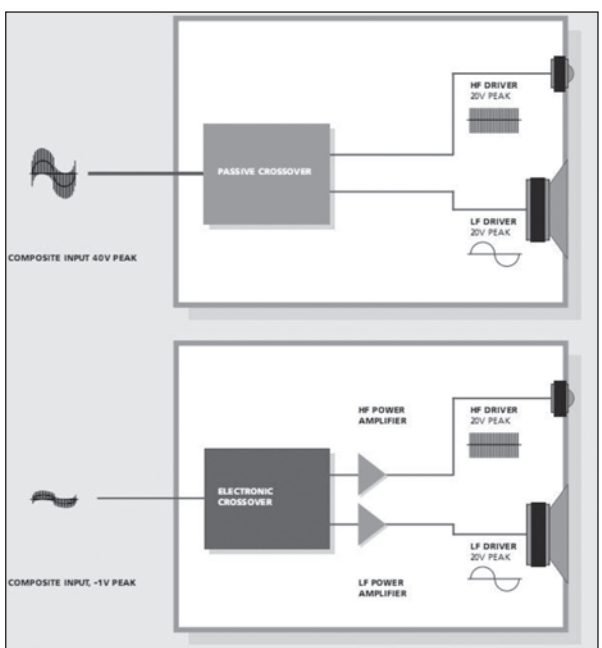

FIGURE 1: Block diagrams of passive (upper) and active (lower) loudspeakers.

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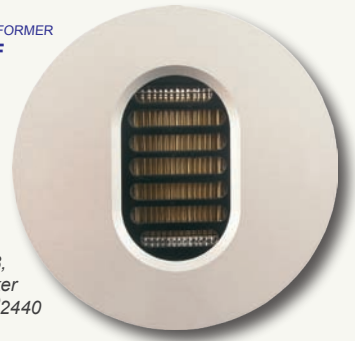

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three-way loudspeakers, respectively. The power amplifiers are connected directly to the loudspeakers, again using cables but in multiple pairs. Signal processing including but not limited to crossover, equalization, and phase compensation can be implemented in the analog (continuous time) domain, typically using RC networks and operational amplifiers or in the digital (discrete time) domain using software.

Some companies have implemented operational amplifiers using discrete components or even valves to implement low-level operational amplifiers. The fact is that unlike in the analog domain, in the digital domain the signal is a number that can be preserved or processed to a high precision.

Although an analog active crossover can result in significant loudspeaker performance gains, implementing digital signal processing (DSP) essentially eliminates any degradation of the low-level signal and adds levels of flexibility and capability to signal processing that are just not possible or cumbersome for analog implementations with the inherent degradation of the analog signal as the complexity of signal processing is increased.

With that in mind, what if the DSP setup was via user-friendly Windows software allowing implementations of relative gain, time delay, filters, limiters, and expanders with the mouse on the user's PC? And what if you could import loudspeaker frequency response LMS acquisitions or equivalent to tailor filtering or equalization to obtain some target response, typically flat? This can, and in the limit, should be the in-room response or the in-room power response (an averaging of acquisitions at predefined on- and off-axis microphone positions throughout the listening room).

Finally, you have the option to implement signal processing that best suits drivers, amps, and enclosures in the listening room. DSP could also be used to equalize, filter, or phase compensate a full-range (single transducer) loudspeaker, which would then require only one power amplifier per channel. In the limit and with respect to "less is more" but requiring a very wide bandwidth transducer, the latter could result in very high performance.

With regard to active loudspeakers, because the power amplifiers do not see RLC networks and each amp is band limited to the bandwidth of the respective transducer, the amplifiers are used more efficiently and, frankly, more effectively with a reduction in intermodulation and harmonic distortion. The passive RLC crossover network effectively disconnects the transducer from the power amplifier for out-of-band frequencies, leaving the transducers' cones and domes free to vibrate passively driven by the relative sound pressure. Now if the amplifiers are compact and reasonable mass, then you can mount the DSP electronics and the amps within the loudspeaker enclosure. This simplifies and effectively reduces the number of components within the audio system, et al.

All you need to complete the A/V system are the input components such as FM tuner, CD/DVD player, TV/monitor, PC/MAC, and a preamplifier with low-level out (these may include home theater DSP of its own, along with the

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active loudspeakers).

Active loudspeakers facilitate enclosure design and alignments that consider the electromechanical and acoustic parameters. ***Figure 2*** illustrates a 6th-order high-pass woofer response. The transducer is 2nd-order high-pass, the ported box is 2nd-order high-pass, and the active filter is also 2nd-order high-pass. The net result of the cascading of the electromechanical and acoustic filters is 6th-order high-pass response. You can apply the same basic methodology to an equalized sealed box with the result being 4th-order high-pass response without the tuning null in the displacement magnitude.

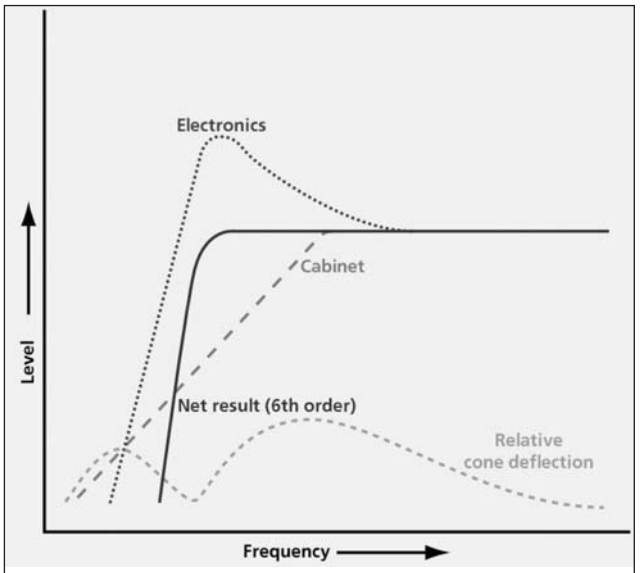

FIGURE 2: Illustration of an actively equalized ported box woofer response.

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Movers and Shakers

It would seem convenient to use an efficient class of power amplifier such as Class-D, which would limit power supply size and heat. Although two or three amplifiers are required for two- and three-way loudspeakers, respectively, a single high performance switching power supply can be utilized for the power amplifiers, and others. Having said that, one company stands out in the development of high performance Class-D power amplifier modules—B&O ICEpower. The ASP modules include 115/230V at 50/60Hz power supply (http://www.icepower.bang-olufsen.com/en/solutions/speaker/ASP_SERIES), while the A series modules come without power supply but utilize the power supply from the ASP module (http://www.icepower.bang-olufsen.com/en/solutions/speaker/A_SERIES).

You can use other amplifiers, but the ICEpower modules offer high power ratings with the highest performance and very low output impedances and the ability to comfortably drive a 2W load. This offers further flexibility in transducer design and selection.

Using very high power amplifiers (mega-amps) with very low output impedance (high damping factor) and low noise and distortion connected directly to the loudspeaker transducers represents the best possible system topology. Then the utilization of DSP for crossover and EQ bring the performance potential to the very highest levels.

One company that has been committed to active DSP loudspeakers since 1991 and has emerged as a leader in the development of active DSP Loudspeakers is Meridian. ***Photo 1*** shows the Meridian DSP8000 active DSP loudspeaker with a MSRP of $79,999/pair. When I interviewed Neville Thiele (Jan. 2005), I asked him what company he thought was performing the most important R&D, and he replied, "This must be a very selective estimate but I would say Bob Stuart, Peter Craven, and Rhonda Wilson at Meridian on loudspeakers and lossless digital coding." Here's a video of Bob Stuart discussing the benefits of Active DSP Loudspeakers http://uk.cinenow.com/videos/318-meridian-bob-stuart-on-digital-dsp-loudspeakers.

Other mostly professional audio companies such as Genelec have done some work in this area; however, most companies have yet to implement active DSP loudspeakers.

KSC in San Diego, Calif., (http://kscind.com/home.html) has developed turnkey solutions to active DSP loudspeaker implementations. They have developed proprietary D-Pro Windows software

PHOTO 1: The Meridian DSP8000 active loudspeaker.

and hardware DSP boards with A/D and D/A on board. The following DIGMODA models with the respective ICEpower modules are available (http://www.digmoda.com).

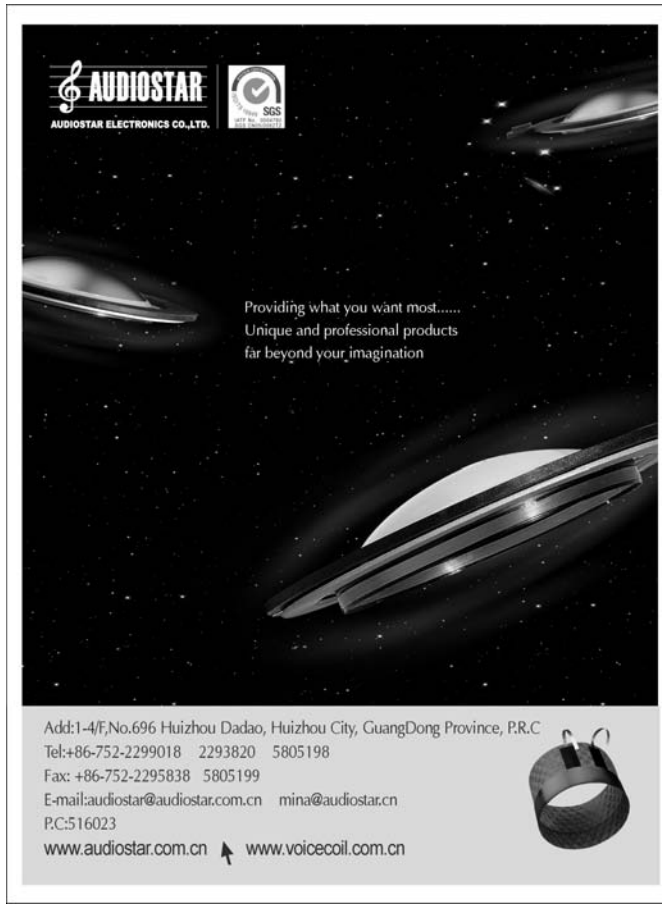
2-channel
DC-520, 500ASP + 250A
DDC-550, 500ASP + 500A
DDC-1050, 1000ASP + 500A
DDC-1100, 1000ASP + 1000A

3-channel
DDC-552, 500ASP + 500A + 250A
DDC-1150, 1000ASP + 1000A + 500A

Subwoofers
DDC-500SW, 500ASP
DDC-1000SW, 1000ASP

DSP boards with D-Pro software only
DP130, 1-channel in × 3 out
DP240, 2-channel in × 4 out

Photo 2 shows the DDC-552. The DIGMODA electronics are packaged with large integral heatsinks and a convenient mounting flange. Custom models are also available in reasonable minimum order quantities, and the DSP boards and D-Pro software are available separately, for those companies



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that wish to use their own amplifier designs.

A company can literally "almost catch up" with Meridian by implementing DIGMODA into new product development of active loudspeakers including subwoofers and two- and three-way loudspeakers. The D-Pro software is friendly and good support is available from KSC and their representatives. Pricing, which depends on quantity purchased and must be quoted by KSC, is surprisingly low for such a high performance product. In Asia and Australia/New Zealand, support for DIGMODA and D-Pro is available from S. M. Audio Engineering.

PHOTO 2: DIGMODA DDC-552.

In addition to the performance aspects of an active DSP loudspeaker, the development of such products is simplified through the implementation of DIGMODA. So much can be done with the DSP with regard to equalization and compensation that the results are essentially assured. Upgrades of transducers and enclosures can be implemented with only changes to the software setup. Additionally, a single DIGMODA model can be used with several loudspeakers with again only a change to the software setup. Finally, products can be brought to market more quickly and with lower development costs.

Installers of custom A/V systems should find DIGMODA useful in implementing very high performance systems that can meet a wide variety of user needs. This includes, but is not limited to, in-wall and in-ceiling applications. These applications seem to also suggest that DIGMODA would be an excellent solution for kit loudspeakers from small manufacturers.

Furthermore, the flexibility and capability of DIGMODA makes implementing other technologies such as new transducers or an actively equalized trick enclosure a reasonable task and with available support should not present any significant problems. The use of the limiter functions can save expensive transducers and eardrums and reduce warranty claims and

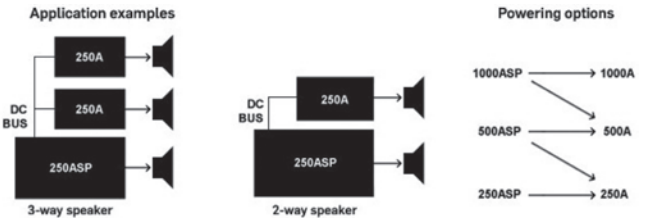

FIGURE 3: Illustration of the configuration of ICEpower modules for three-way and two-way loudspeakers.

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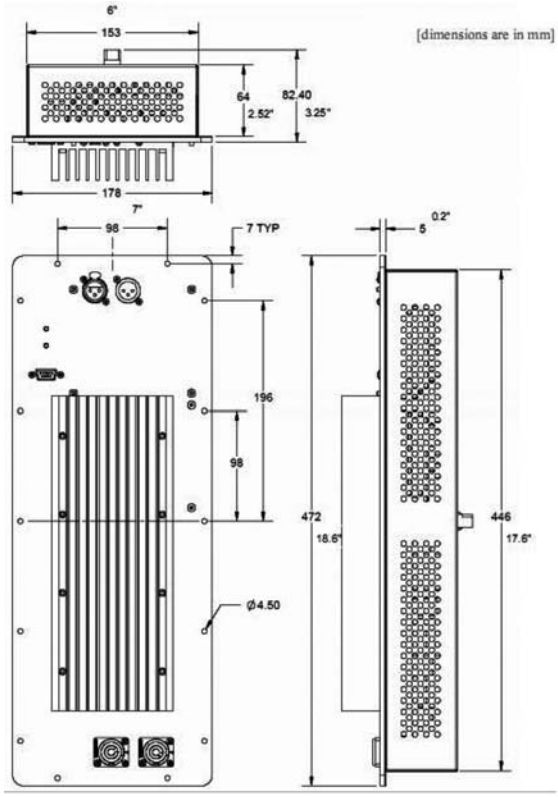

FIGURE 4: Mechanical drawing of the DIGMODA DDC-552 with dimensions.

thus improve product reliability.

The typical audio specifications of the DIGMODA DDC-552 are as follows: Dimensions of the DDC-552, DDC-550, and DDC-520 are illustrated in ***Fig. 4***. For those who want to use amps other than the ICEpower, KSC's DSP boards DP130 and DP240 are available. The DP130 is one channel in, three out, and the DP240 (***Photo 3***) is two channels in, four out.

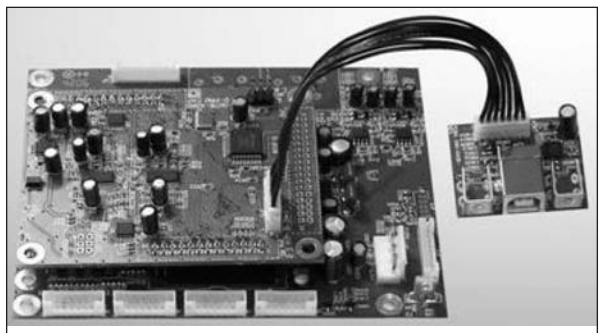

PHOTO 3: KSC DP240 DSP board (two channel in, four out) with A/D converter.

D-PRO SOFTWARE

D-Pro software utilizes virtual instruments that are intuitive and easy to use. You wire the DSP by connecting the input to the DSP channels and selecting the outputs with the PC mouse.

The D-Pro software is typically downloaded from KSC's

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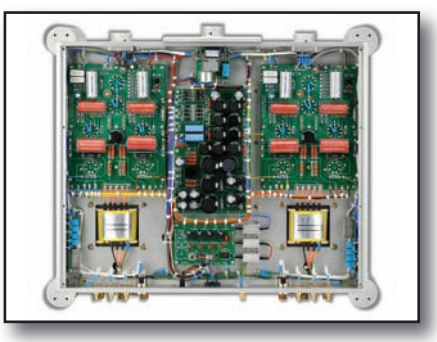

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FTP server. Once D-Pro is installed (Windows XP recommended), you connect the PC to DIGMODA with a common USB printer like interconnect. There are two main screens that require setup. The first screen is shown in ***Fig. 5***. Here you wire the inputs with respect to the DSP channels and outputs.

The second screen contains the DSP blocks as shown in ***Fig. 6***. Clicking on the respective DSP block opens a control screen. The control screens for each block and sub-block are shown in ***Figs. 7-13***.

Figure 7 shows the user-selected FIR 2nd-order filter setup screen. Up to 16 filters are available for each channel. The filter types are selected by number code.

1 = Low-Pass
2 = High-Pass

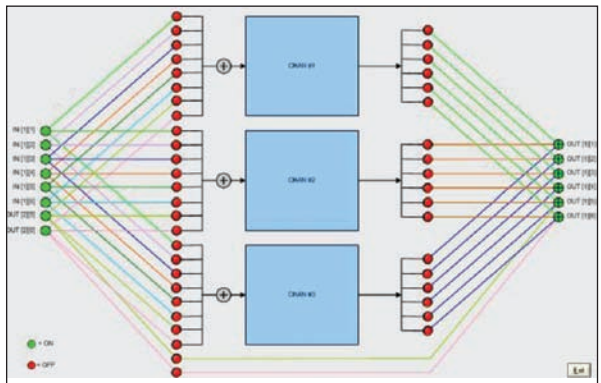

FIGURE 5: Input to outputs routing configuration screen.

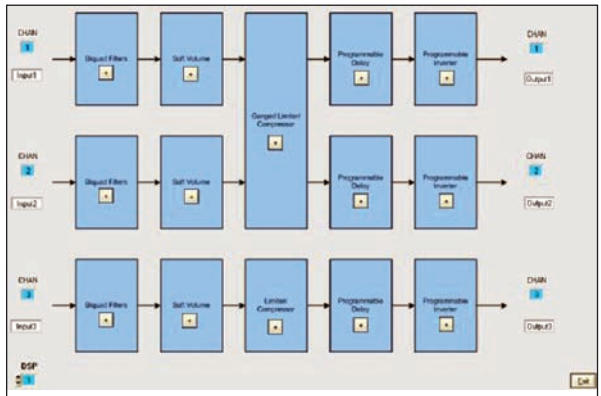

FIGURE 6: DSP block selection screen

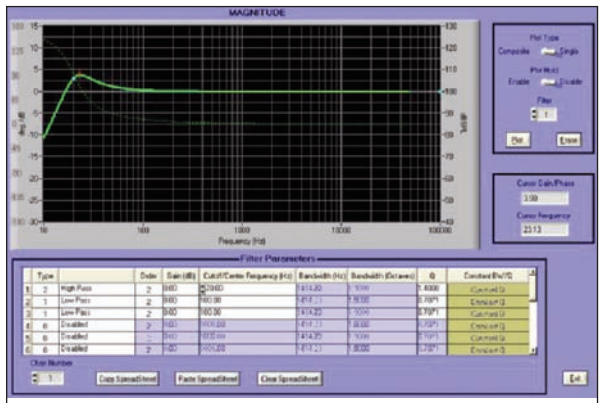

FIGURE 7: 2nd-order filter implementation screen.

3 = BandPass
4 = All-Pass
5 = Parametric EQ (peak or notch)
6 = Bass Shelf
7 = Treble Shelf
Then either enter gain, frequency, and Q or use the mouse to drag the curve to the desired filter response.

In room frequency, response acquisitions can be utilized as an interim evaluation as the appropriate filters are determined and applied with the PC mouse to equalize the response with respect to some target response curve. ***Figures 8*** and ***9*** show LMS response acquisitions before and after EQ and with tweeter phase invert.

The gain control, shown in ***Fig. 10*** allows tweaking the

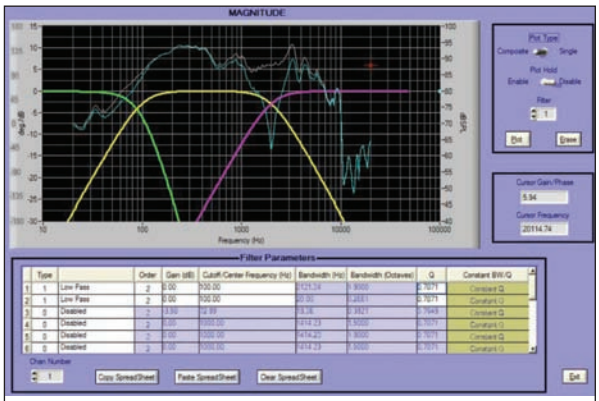

FIGURE 8: Filters responses with LMS acquisitions overdrawn before EQ with and without invert tweeter.

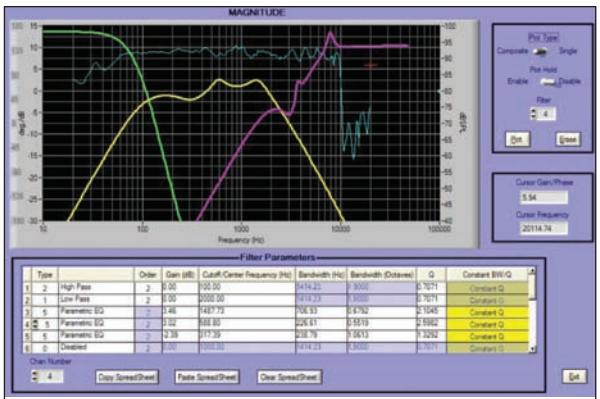

FIGURE 9: Filters responses with LMS acquisitions overdrawn after EQ.

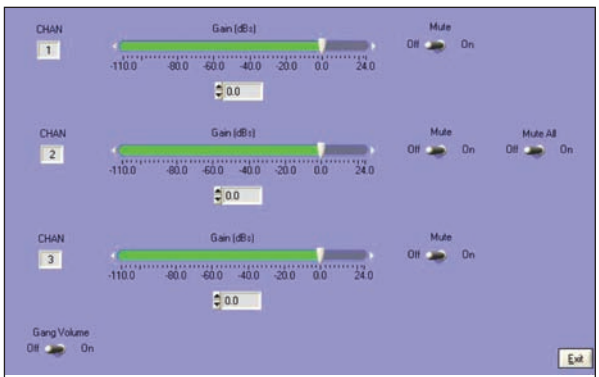

FIGURE 10: Gain control screen.

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relative levels of transducer input signals. ***Figure 11*** shows an interesting screen that reminds me of the old DBX 3BX dynamic range expander that was sold from 1984-1986. These were similar to open-ended noise reduction but also allowed high power delivery to the loudspeaker on transient peaks. They were based on analog compander chips.

Perhaps a more common use of these controls is to implement a gated limiter such that the transducer(s) will be protected dynamically, especially the tweeter. However, the possibilities from this control screen seem limitless.

Figure 12 shows the screen for time adjustment that can be adjusted with the PC mouse using onboard memory. Each screen setup is independent of another. Once the setup is completed, a binary file containing the setup can be saved. D-Pro can read and write setup files. Suddenly, passive networks seem primitive and analog electronics seem cumbersome.

DIGMODA is an exciting and innovative product that is "fun" to use. Additionally, DIGMODA brings the A/V system closer to a convergence system that utilizes the

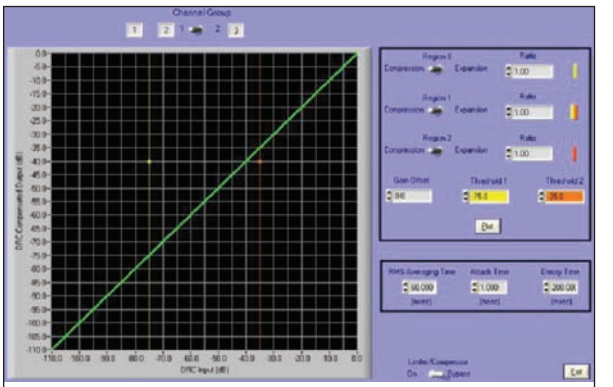


FIGURE 11: Dynamic compression-expansion implementation screen.

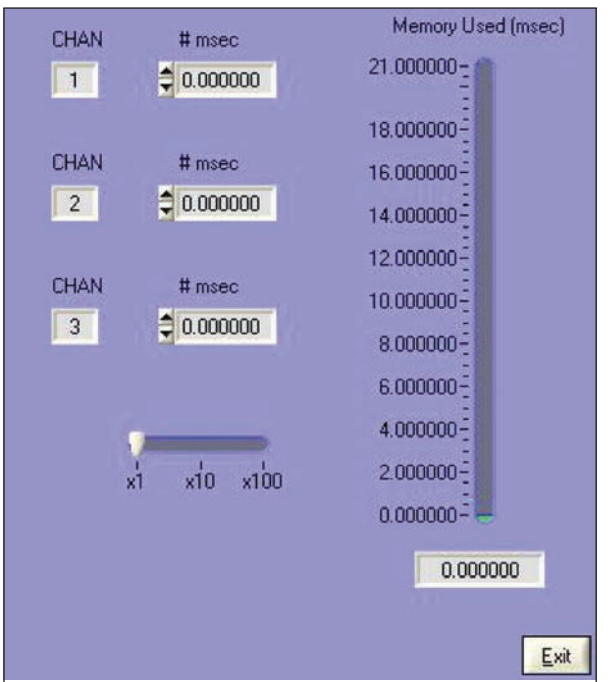


FIGURE 12: Time delay control screen.

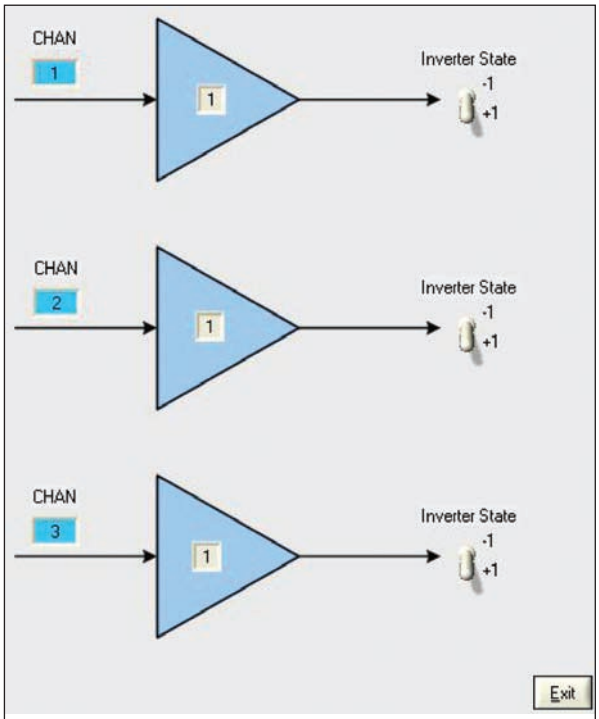


FIGURE 13: 180° phase invert screen.

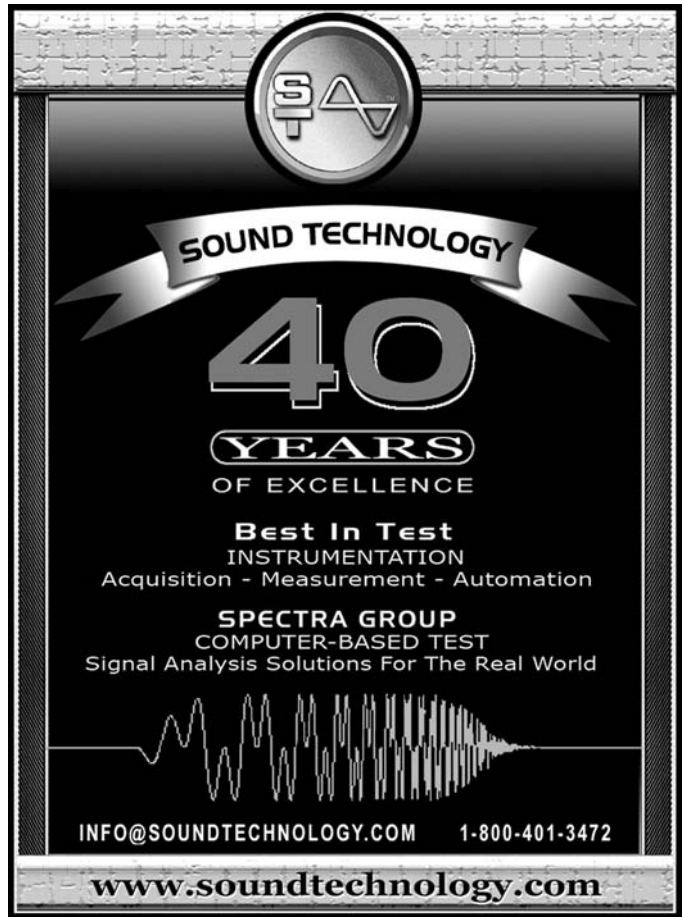
family PC as a powerful but easy-to-use signal processor including effects and, along with the Internet, as a source of program material. ***Fig. 13*** shows the controls for relative phasing of the transducers that can be implemented with the PC mouse.

OTHER PERFORMANCE CONSIDERATIONS

With state-of-the-art electronics now available in an easy-to-use turnkey solution, the requirements for transducers must also be at a high standard to realize the highest performance. Frankly, the transducers are still the weak link in the performance chain of an A/V system. S. M. Audio's solutions are *STEALLUS X* woofer, *STEALLUS* mid/bass, and *STEALLUS Air Core* tweeter. However, there are several manufacturers and distributors of other high performance transducers.

High performance engineering materials can also play a role in the quest for A/V perfection. Diaphragm and cone materials such as beryllium foil, magonite (keronite process applied to magnesium), and sandwich composites can reduce mass and eliminate frequency-related bending. Carefully designed molded TEEE, treated Acrylic, and Nomex surrounds and spiders can improve suspension linearity.

Klippel GmbH is engaged in nonlinear system R&D regarding a proprietary chip that would compensate for nonlinearity in the large signal parameters, Bl(x), Le(x,i), Kms(x) along with the thermal characteristics of the loudspeakers' transducers. First these large signal parameters are acquired with a KLIPPEL DA and then the chip is "taught" these dynamic nonlinearites. A nonlinear correction or compensation signal is then convolved with the low-level input signal. The result is dynamic reduc-



Audio Specifications				
Parameter	Conditions	Typical	Maximum	Unit
THD+N in 4Ω (AES17 filter)	f = 40 Hz, Po = 1W	0.009	0.011	%
	f = 500 Hz, Po = 1W	0.025	0.031	
	f = 1 kHz, Po = 1W	0.019	0.024	
THD+N in 8Ω (AES17 filter)	f = 40 Hz, Po = 1W	0.007	0.009	
	f = 500 Hz, Po = 1W	0.016	0.020	
	f = 1 kHz, Po = 1W	0.013	0.016	
Maximal THD+N in 4Ω (AES17 filter) -10dBFS	f = 40 Hz	0.006	0.008	%
	f = 500 Hz	0.008	0.010	
	f = 1 kHz	0.010	0.013	
Maximal THD+N in 8Ω (AES17 filter) -10dBFS	f = 40 Hz	0.006	0.008	
	f = 500 Hz	0.008	0.010	
	f = 1 kHz	0.010	0.013	
THD+N Low Level in 4Ω	f = 40 Hz, 100 mW	0.02	-	%
	f = 500 Hz, 100 mW	0.04	-	
	f = 1 kHz, 100 mW	0.07	-	
THD+N Low Level in 8Ω	f = 40 Hz, 100 mW	0.02	-	
	f = 500 Hz, 100 mW	0.04	-	
	f = 1 kHz, 100 mW	0.05	-	
Nominal Voltage Gain (A_v)	f = 40 Hz	29.92	-	dBV
	f = 500 Hz	29.97	-	
	f = 1 kHz	29.98	-	
Frequency Response (Po = 1W)	f = 20 Hz - 100 kHz	±0.5	±1	dB
	f = 100 Hz - 2 kHz	±0.5	±1	
	f = 2 Hz - 20 kHz	±0.5	±1	
Common Mode Rejection (CMR)	20 Hz - 200 kHz	-55	-	dB
Signal to Noise Ratio in 4Ω (SNR)	0db=1% THD, 40 Hz	-135	-	dB
	0db=1% THD, 550 Hz	-125	-	
	0db=1% THD, 1 kHz	-110	-	
Signal to Noise Ratio in 8Ω (SNR)	0db=1% THD, 40 Hz	-136	-	
	0db=1% THD, 500 Hz	-125	-	
	0db=1% THD, 1 kHz	-105	-	
Input Impedance (Z_{in})	Unbalanced	18	-	kΩ
	Balanced	36	-	
Input Sensitivity in 4Ω (Balanced) (V_{in})	f = 40 Hz, 500W	1.43	-	Vms
	f = 1 kHz, 500W	1.42	-	
	f = 40 Hz, 225W	0.99	-	
Input Sensitivity in 8Ω (Balanced)	f = 500 Hz, 225W	1.42	-	
	f = 500 Hz, 225W	1.40	-	
	f = 1 kHz, 112W	0.95	-	
DC Output Offset in 4Ω (DC_{out})	Low channel	3.0	-	mVms
	Mid channel	3.3	-	
	High channel	4.3	-	
DC Output Offset in 8Ω (DC_{out})	Low channel	9.5	-	
	Mid channel	4.0	-	
	High channel	4.3	-	
Input Clipping (V_{rms})	f = 1 kHz	12	-	dBU
Damping Factor (DC_{out})	f = 100 kHz, R_L = 8Ω	2000	-	-

TABLE 1

tion in IM and THD at the root cause, the transducers' motors and suspensions.

If readers have questions, concerns, interests, or comments regarding active DSP and high performance loudspeaker products and applications, feel free to contact me at steve@s-m-audio.com. *VC*

Steve Mowry is currently an independent researcher and consultant in transducer, loudspeaker, headphone design, and new product development, along with being a frequent contributor to *Voice Coil* and *MultiMedia Manufacturer*.

NeoPro5i、NeoCD2.0、NeoCD3.5H、NeoCD3.0、NeoCD1.0 .....

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